ORIGINAL ARTICLE

Comparison of CT Angiography and Intra-Operative Findings of Renal Vascular Anatomy in Living Donor Kidney and its Diagnostic Accuracy

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ABSTRACT

Background: The treatment of choice for end-stage renal disease is renal transplantation, which can be done from living or deceased donor. Living donors with multiple vessels lead to higher risk of allograft dysfunction. To select the patient and the kidney to be harvested, renal donors are radiologically evaluated before surgery. Multidetector-row computed tomography (MDCT) angiography is minimally invasive & has the advantage of assessing the main vessels (renal vein, renal artery), ureteral structure, renal parenchymal lesions, renal cystic diseases, tiny stones & surrounding anatomic variants with one test.

Study objective: To assess the accuracy of CT angiography in predicting the anatomy of renal vessels

Design: Retrospective study on 70 patients.

Sample/population: Patients who underwent open/ laparoscopic live donor nephrectomy in SMS Hospital, Jaipur

Duration of study: 2 years & 6 months

Results & Conclusion: CT angiography helps in accurately mapping the vascular anatomy, strategic planning of the surgery in terms of vascular dissection and helps in avoiding vascular complications.

Key words: CT angiography, Donor nephrectomy, Renal transplantation, Renal vascular anatomy.

INTRODUCTION

The treatment of choice for end-stage renal disease is renal transplantation, which can be done from living or deceased donor. Although, majority (>95%) of kidney transplantation are from living donors. It is essential to perform anatomical vascular evaluation of the donor kidneys to determine the suitable surgical approach and select the kidney to be used[1].

In living donor renal transplantation, preoperative anatomic and functional evaluation of donor kidneys for selection of a suitable donor is necessary for planning surgery, to decrease hospital stay and blood loss by reducing complications and to accelerate recovery[2,3]. Renal transplantation with living donors having multiple renal vessels carries higher risk of allograft dysfunction and thereby also carries poor long-term prognosis in the recipient. This is because multiple vessels require more anastomosis time, prolongs warm ischemia time and resulting in poor graft outcome.

To select the patient and the kidney to be harvested, renal donors are radiologically evaluated before surgery. Precise preoperative vascular mapping is required in donors with multiple renal vessels. There has been a revolution in the technology with respect to the quality of three-dimensional (3D) images and the speed of scanning with the introduction of multi-detector row computed tomography (MDCT). Even though CT and magnetic resonance (MR) imaging have comparable accuracy, CT has a higher resolution than MR and is more technically robust. For living kidney donation, assessment of potential renal donors can be done by a minimally invasive and well-established method, which is Multidetector-row computed tomography (MDCT) angiography. It is a minimally invasive and well-established method for assessment of potential renal donors and obtaining kidney anatomy for the purposes of living kidney donation[4-9]. MDCT angiography has the advantage of assessing the main vessels (renal vein, renal artery), ureteral structure, renal parenchymal lesions, renal cystic diseases, tiny stones & surrounding anatomic variants with one test[7,10]. CT angiography has 100% sensitivity identifying accessory arteries and 93% sensitivity identifying pre-hilar arterial branches.

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There is a dearth of evidence regarding the accuracy of detecting the vascular anatomy by CT angiography. The accuracy of determining the vessel structure by CT angiography has been assessed in earlier studies. The accuracy for the main vessels was reported to be 90% to 100% and that for the minor vessels was 75% to 100%[11-13].

Therefore, in our study, we retrospectively analyzed the accuracy of vessel structures obtained by CT angiography compared with the actual vessel structure observed during surgery.

AIMS AND OBJECTIVES

1. To compare the CT angiography findings on the operated side with the intraoperative findings.
2. To assess the accuracy of CT angiography in predicting the anatomy of renal vessels.

METHODS

With appropriate clearance from Institutional Ethics Committee, this single center analytical, retrospective study was done on 70 consecutive patients who underwent open/laparoscopic live donor nephrectomy from December 2019 to May 2022.

MDCT (Multidetector computed tomography) renal angiography was done in all donors pre- nephrectomy. All patients were scanned from the dome of the diaphragm down to the pelvis by a 128-slice MDCT scanner. The contrast medium used was low osmolar non-ionic contrast medium (IOHEXOL) containing 300 mg/ml of iodine, was injected through the peripheral venous line via a pump injector with a volume range between 120 and 150 ml (according to the patient's weight 1.5–2 ml/kg). MDCT comprises of unenhanced, arterial, nephrographic and delayed phases. The unenhanced phase has a goal to locate the kidneys, rule out calculi and provide a baseline analysis to compare the enhancement of subsequent lesions. Contrast-enhanced CT was initiated 30 seconds, 55 seconds, and 10–15 min after the injection to coincide with the arterial, venous and excretory phases, respectively. For arterial and nephrographic phases, a minimum of 1-mm sections were used for a better visualization of accessory renal arteries.

The assessment was done for the presence of number of arteries, early branching arteries, and accessory arteries. Accessory renal arteries are independent of the main renal arteries and have a discrete origin from the aorta or iliac arteries. Diagnosis of an early branching renal artery is made, when a branch diverges within 2.0 cm in the retrocaval segment (right kidney) or from the lateral wall of the aorta (left kidney). Venous anatomy was evaluated in the arterial phase and in addition by images in the nephrographic phase, especially for assessment of accessory renal veins, which sometimes enhanced later.

The findings of CT scan from the stored archives of our hospital were noted. The parameters noted in the CT angiography were artery and vein number on each side, any pre-hilar branching, relationship of the artery to the vein and other morphological abnormalities or any other incidental findings.

EXCLUSION CRITERIA for kidney donation was:

Donors with a history of-

1. Diabetes mellitus
2. Hypertension requiring 3 or more anti-hypertensives
3. Morbid obesity >35kg/m2
4. Active drug abuse
5. Psychiatric disorders
6. Positive virology
7. Significant cardiovascular disease

Donor nephrectomy was done after approval by the transplant board of the hospital and after due clearance from the regulatory authorities. Donor nephrectomy was done using an open/laparoscopic approach. The intraoperative findings noted were the artery and vein number, pre-hilar branching.

The findings on CT were compared with the intraoperative findings on the operated side.

Details about the vascular anatomy and morphology variations were abstracted.

STATISTICAL ANALYSIS

Chi-square test was used to compare the variables among the groups, and a p-value of <0.05 was considered significant. SPSS ver. 20.0 was used for performing the statistical analysis.

RESULTS

Of the 70 patients who underwent live donor nephrectomy, 46 were females and 24 were males. 69 patients underwent left donor nephrectomy and one patient underwent right donor nephrectomy. Laparoscopic left donor nephrectomy was done on three male patients and five female patients, out of 70 patients. Of the 70 patients who underwent donor nephrectomy, single renal artery and single renal vein were present in 16 (23%) male patients and 33(47%) female patients which accounts for total of 49 (70%) patients. 12 (18%) females and 4 (6%) males had double renal artery. Double renal vein found in two male donors. Two male patients had both double artery and vein. Triple renal artery was found in four male patients and one female patient, triple renal vein was found in none of the patients. Single renal artery and vein was found in patient who underwent open right donor nephrectomy. (Table 1) The CT scan was able to identify pre-hilar branching in five patients, with similar intra-operative finding. The CT angiogram showed retro aortic left vein in two patients and circumaortic renal vein in one patient. (Table2)

Single renal artery and vein were found in 72.8% patients on CT while intra-operatively it was found in 70% patients. Double artery was found in 24.28% patients on CT and 22.85% intra-operatively. Triple artery was found in 2.8% on

CT and 7.2% intraoperatively. Double vein was found in 1.4% patients on CT and 2.8% intraoperatively. (Table 3)

The positive predictive value for single artery was (96.08%), single vein (98.55%), double artery (82.35%), double vein (100%) and triple artery (100%) and negative predictive value in our study for single artery (100%), single vein (100%), double artery (96.23%), double vein (98.55%) and triple artery (95.59%). (Table 4)

The CT angiography findings of renal vascular anatomy in living kidney donor was found accurate and statistically similar to intra-operative findings. ($p<0.001$)

Table 1: Representing intraoperative statistics

	Male (%)	Female (%)
Number	24 (34%)	46(66%)
OLDN	20 (28.6%)	41(58.6%)
ORDN	01 (1.4 %)	0
LLDN	03 (4.3%)	05 (7.1%)
LRDN	0	0
Single artery	16 (22.8%)	33 (47.1%)
Double artery	04 (5.7%)	12(17.1%)
Triple artery	04 (5.7%)	01(1.4%)
Single vein	22(31.4%)	46(65.7%)
Double vein	02 (2.8%)	0

OLDN: Open left donor nephrectomy, ORDN: Open right donor nephrectomy

LRDN: Laparoscopic right donor nephrectomy, LLDN: Laparoscopic left donor nephrectomy

Table 2: Exclusive CT findings on arterial and venous anatomy (70 cases)

	Male	Female
Single artery and Single vein	16 (23%)	35(50 %)
Double artery and single vein	05 (9%)	11(16%)
Double vein and single artery	0	0
Double artery and double vein	01 (1.4%)	0
Triple artery	02 (3%)	0
Triple vein	0	0
Pre-hilar branching	01 (1.4%)	05 (7.14%)

Table 3. Vascular anatomy correlation in CT vs surgery

	CT findings	Intra operative finding
Single artery	51	49
Single vein	69	68
Double artery	17	16
Double vein	01	02
Triple artery	02	05
Triple vein	0	0

Table 4. Comparison of vascular anatomy between CT & surgery

	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)
Single artery	100	90.48	96.08	100
Single vein	100	50	98.55	100
Double artery	87.5	94.44	82.35	96.23
Double vein	50	100	100	98.55
Triple artery	40	100	100	95.59

DISCUSSION

A pair of arteries which arises from the abdominal aorta at the level of the L1 to L2 vertebral bodies, below the origin of the mesenteric artery supply the kidneys in most individuals. At the hilum of the kidney, each renal artery splits into anterior and posterior branches (pre-segmental arteries). Its further divides into segmental arteries to supply the respective segments of the kidney (apical, upper, middle, inferior and posterior). Accessory renal arteries can commence from the abdominal aorta as low (inferiorly) as the internal iliac artery or above the main branch. A frequent variant is when the main renal artery divides prior to reaching the hilum of kidney. This condition is named as extra-hilar branching and when it takes place within 1.5 cm of the renal ostium in the abdominal aorta, it is called early branching. [(4)] Since most surgeons require minimum 2-cm length of renal artery prior to hilar branching to assure adequate control and anastomosis, so it is crucial to recognize any pre-hilar branching. [(5)] The most frequent accessory artery is a polar artery arising from the aorta, close to the origin of the main renal branch, and supplies the inferior renal pole. The upper pole, which is normally a small segment is irrigated by the second most frequent supplementary artery. Considerably more variants of veins can be discovered as compared to the arterial side. The most common is the existence of multiple renal veins, which occurs in 15 %–30 % of patients. [(6)] The most characteristic variant of the left renal vein is the circumaortic renal vein (17 % of patients), as it embraces the ventral and dorsal aorta.

The pre-operative imaging of living renal donors is required to detect renal anomalies so as to select candidates for living renal transplantation, to reduce the risk of surgical complications that can endanger survival of the graft or donor's life. Moreover, the length and the width of the accessory vessel on a CT angiogram aids in

deciding the surgeon the side of donor nephrectomy, and whether to forfeit or save the accessory vessel. The surgeon can decide the side of the donor nephrectomy by seeing early branching, which is seen well on 3D images. Detection of an accessory vessel and its course helps surgeons to avoid inadvertent laceration of an accessory vessel, which results in a focal renal infarct.

In our study, the incidence of single renal artery and vein was 70% which was higher than the literature. The incidence of double renal artery was 23% in our study, which was higher in comparison to the study by Shetty et al.[14] who reported the incidence rate of 17% on the left side.

In our study, the positive predictive value for single artery (96.08%), single vein (98.55%), double artery (82.35%), double vein (100%) and triple artery (100%) and negative predictive value in our study for single artery (100%), single vein (100%), double artery (96.23%), double vein (98.55%) and triple artery (95.59%).

In a study by Shetty et al. [14] the positive predictive value and negative predictive value for venous anatomy in left side correlation was 99.5%. Similarly for arterial anatomy in left side it is was 96.8%. It was 100% for arterial and venous anatomy in the right side.

Pozniak et al.[4] mentioned that sensitivity and specificity for identifying specific vessels was 99.6% and 99.6% for main renal arteries, 76.9% and 89.9% for polar arteries, and 98.7% and 95.5% for main renal veins, respectively.

Satomi et al. [5] found that CT and surgical findings were accurate in 96% of cases for arteries and 99% of cases for veins. Our results are comparable to those from recently published articles about studies of multi-detector row CT in evaluating potential renal donors.

Kim et al.[15] reported that in their series of 77 renal donor's multi-detector row CT had an overall depiction rate of 98% (89 of 91 arteries and 83 of 85 veins).

In general, the prevalence of renal vascular abnormalities in our study was comparable to that found in other studies.

CONCLUSION

Donor nephrectomy requires vital information regarding the vascular anatomy of the kidney. CT angiography helps in accurately mapping the vascular anatomy. CT renal angiography helps in strategic planning of the surgery in terms of vascular dissection and helps in avoiding vascular complications. The incidental findings detected by CT angiography can also help in holistic management of the patient in donor nephrectomy.

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